Complete suppression of reverse annealing in neutron irradiated MCZ Si detectors during gamma irradiation

Z. Li, W. Chen, R. Gul, J. Kierstead
Brookhaven National laboratory, USA
E. Verbitskaya, V. Eremin
Ioffe Physical-Technical Institute of Russian Academy of Sciences
St. Petersburg, Russia
J. Härkönen
Helsinki Institute of Physics, Finland
M. Hoeferkamp, J. Metcalfe, S. Seidel
University of New Mexico, Albuquerque, USA

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Outline

- Background
- Experimental
- I-V characteristics
- Current pulse response
- Reverse annealing suppression by gamma

Conclusions

Background

Goal of the study

Develop radiation hard Si detector
that can utilize mixed irradiation in ILC:

gamma + electrons + neutrons

Task $\Rightarrow$ compensation of donor-type and acceptor-type defects

The task of mixed irradiation is also important for LHC

Experimental

Samples:

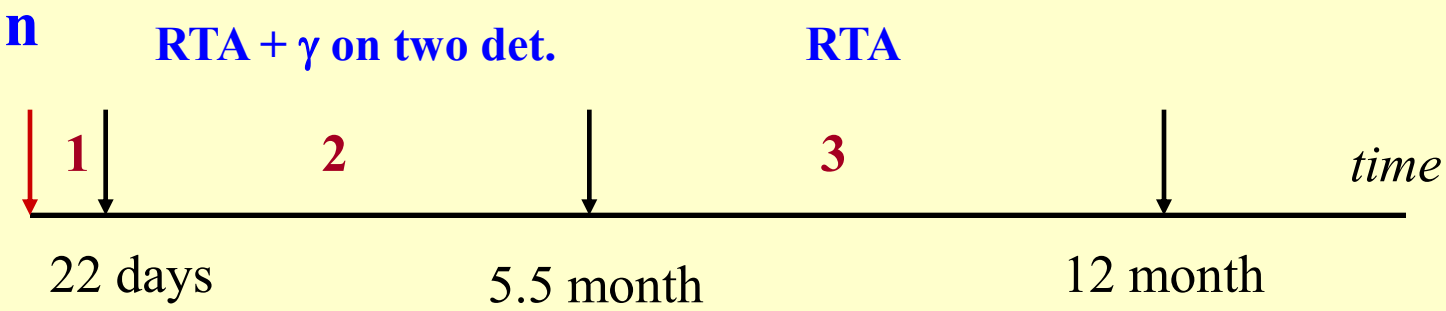
p^+-n-n^+ Si detectors processed in BNL
n-type MCZ Si, $\rho \sim 1$ k, $d = 390$ μm

Characterization (all done at BNL):

- I-V, C-V
- TCT with red laser
- I-DLTS with infrared laser filling

Irradiation and annealing

Neutrons: Research Reactor in Sandia National Lab, 0.8-1 MeV, Hardness Factor is 1.3),
F_n up to $3x10^{14}$ n_{eq}/cm^2
Gamma: BNL's ^{60}Co Radiation facility (1.25 MeV),
to a total dose of 500 Mrad



Sample #	1480-13	**1480-5**	1480-14	**1480-16**
1st irradiation, n_{eq}/cm^2	$1.5x10^{14}$	$1.5x10^{14}$	$3x10^{14}$	$3x10^{14}$
2nd irradiation, gamma (Mrad)	0	500	0	500

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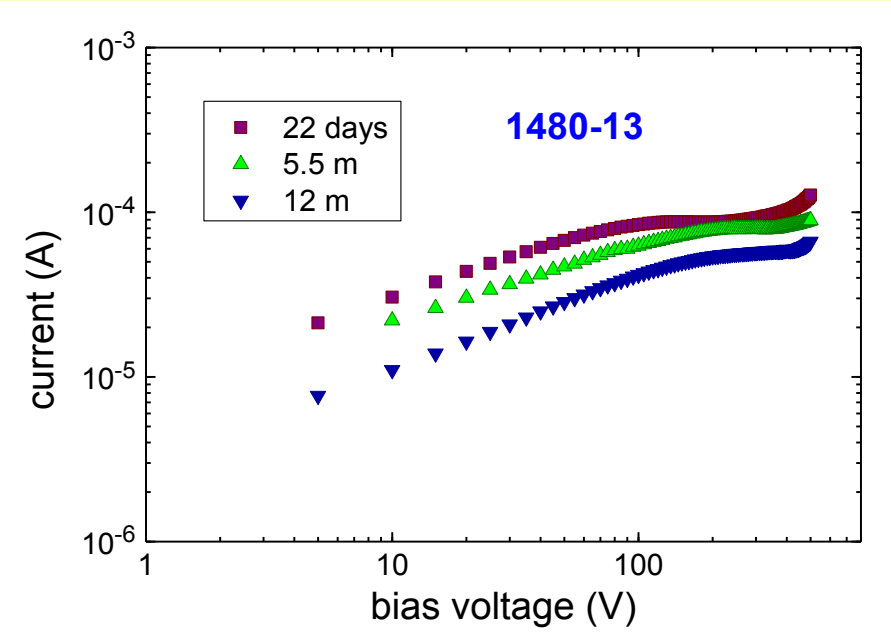
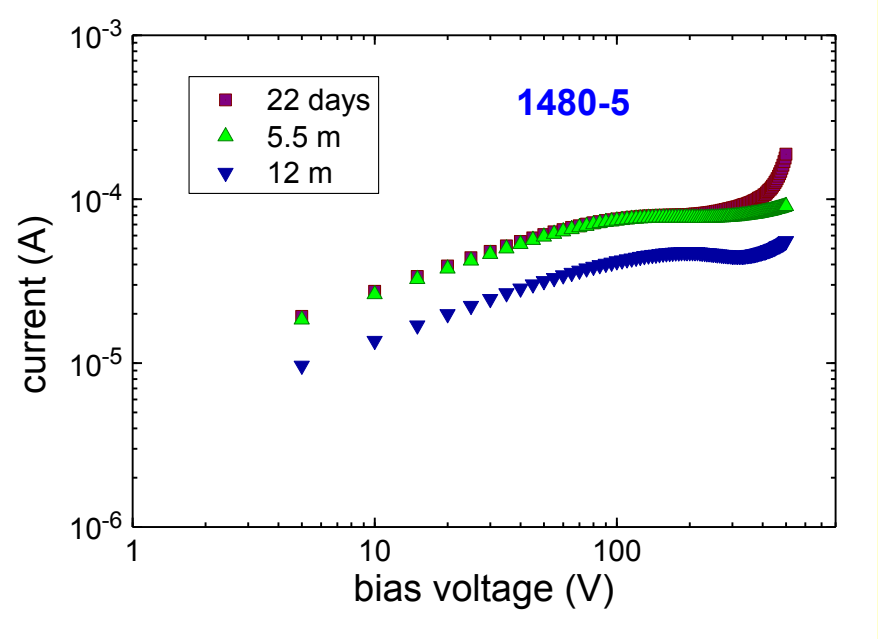
I-V characteristics: influence of gamma

RTA only



Gamma during 5.5 month



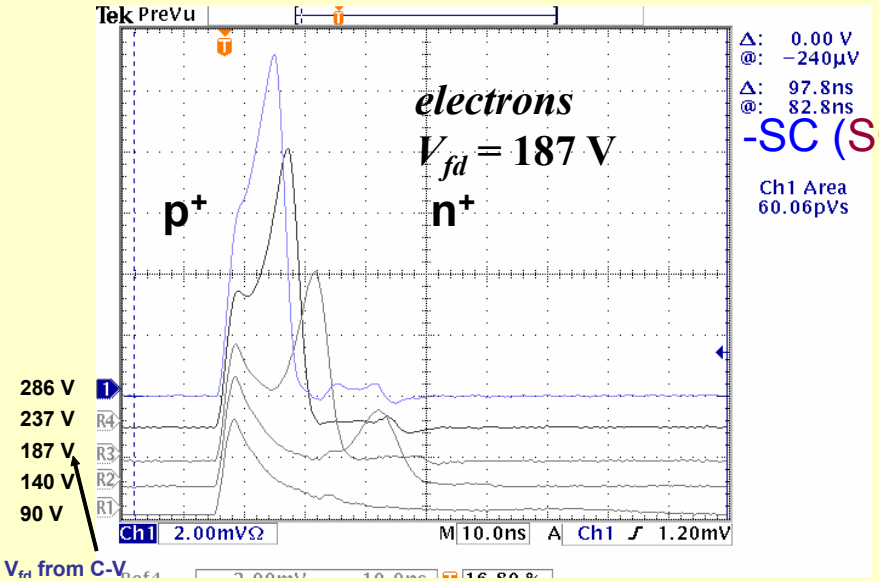
#1480-5: I-V did not change during gamma irradiation

Current pulse response

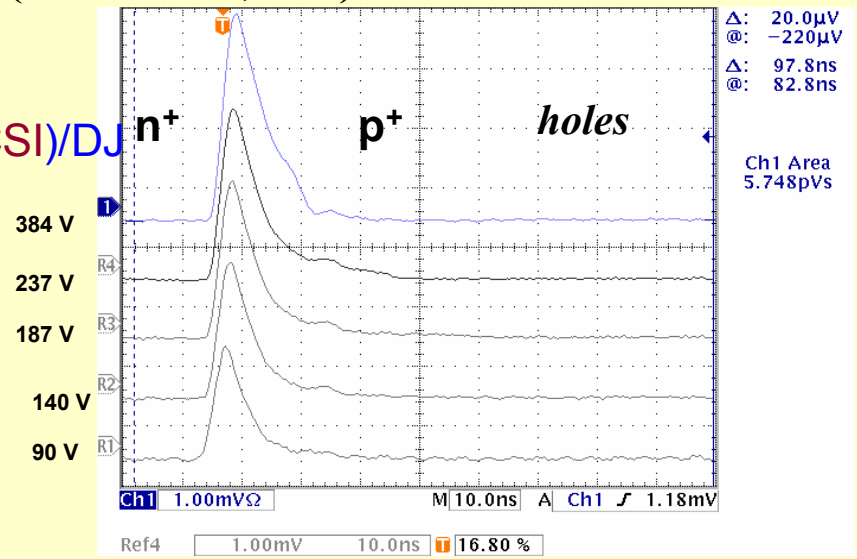
Neutrons only

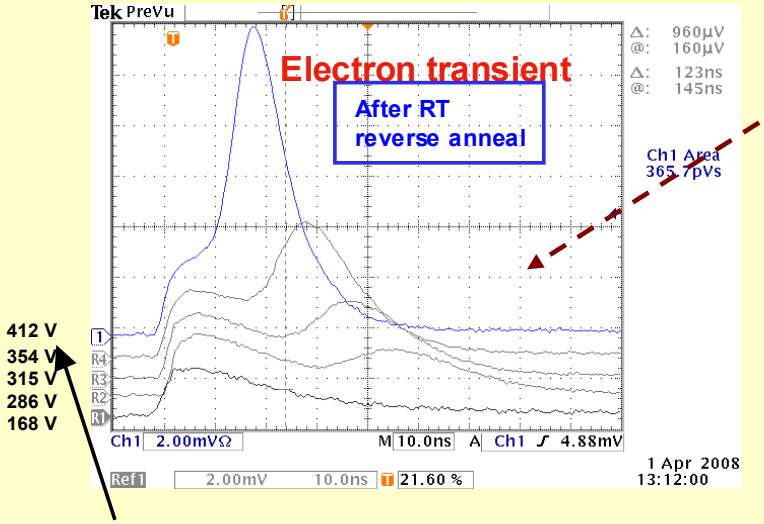
 # 1480-13, $F_n = 1.5 \times 10^{14}$ cm^{-2}

RTA 22 days (1st interval, end)



-SC (SCSI)/DJ





RTA, 5.5 m (2nd int., end)

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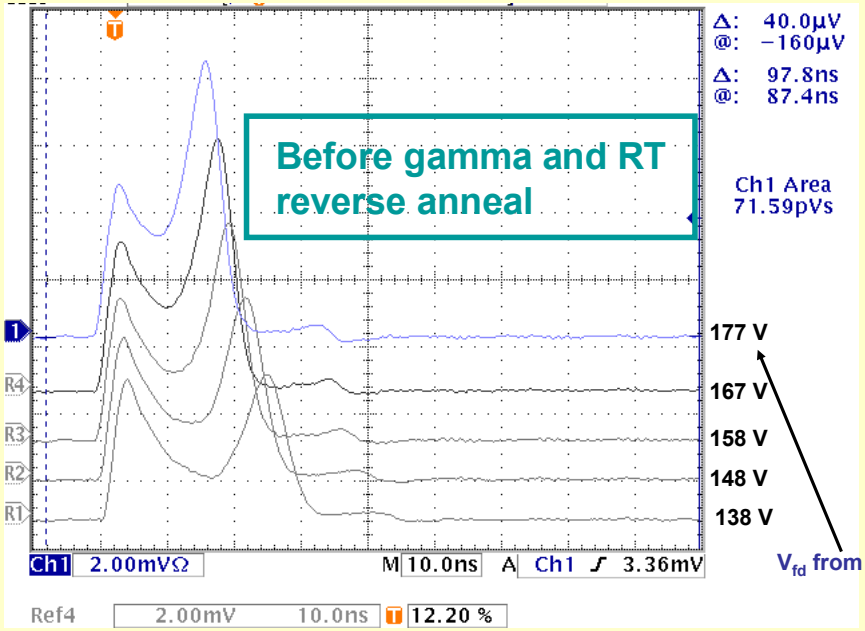
Current pulse response: impact of gamma

#1480-5, **1.5x10^{14} n/cm^2 + 500 Mrad** (lower F_n)

Just after neutrons (1st int., end)

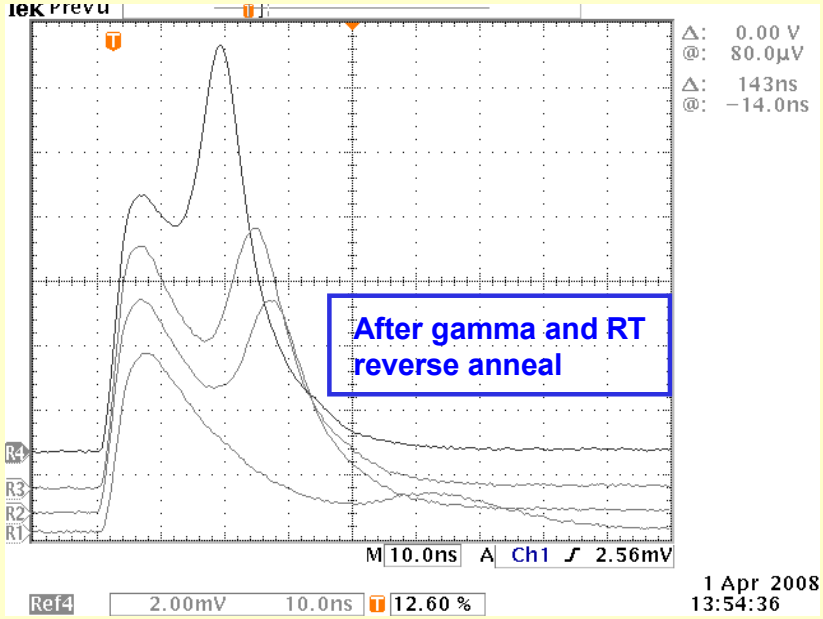


V_{fd} from C-V

160 V
140 V
130 V
91 V

V_{fd}(CV)

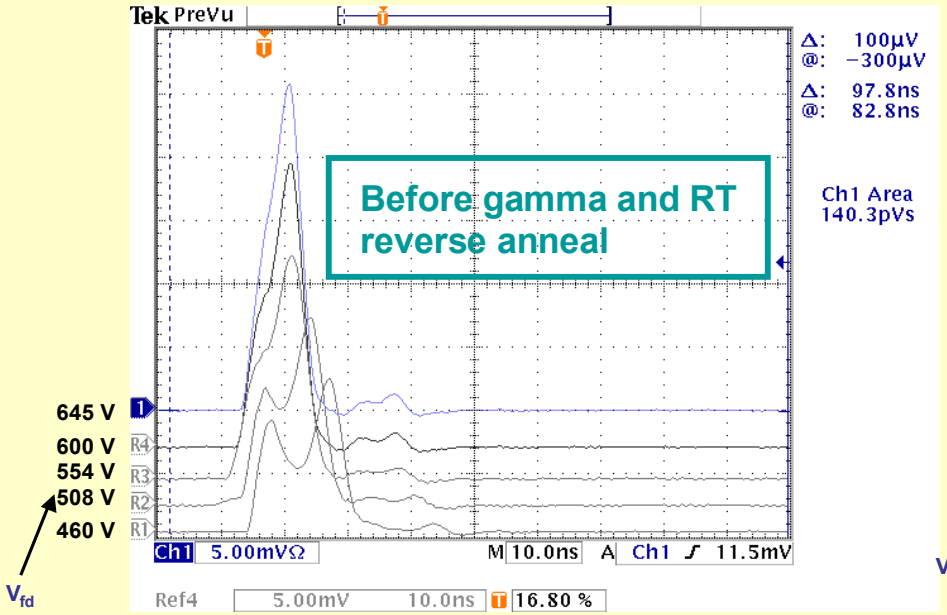
5.5 m RTA + gamma: 2nd int., end

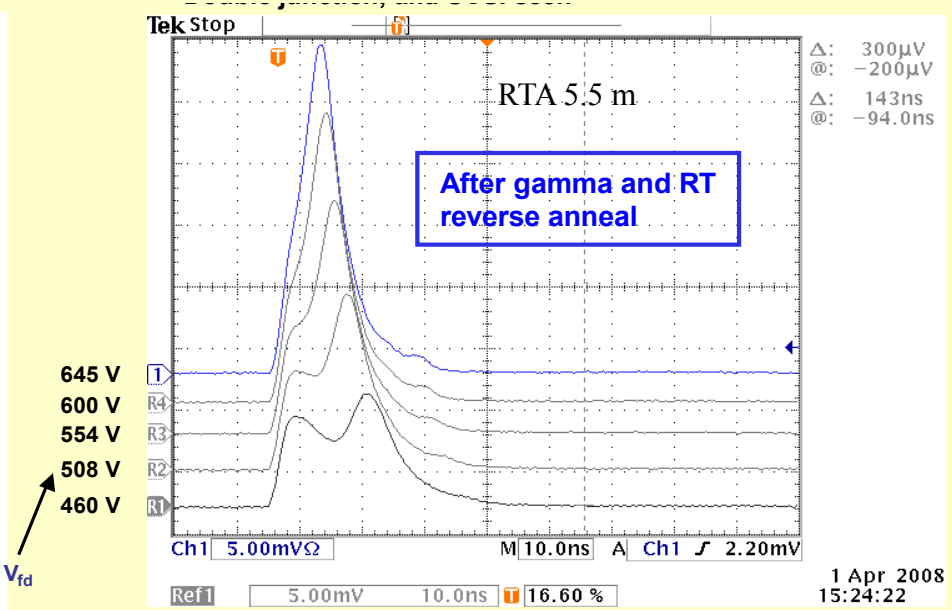


Pulse shapes and V_{fd} are similar

Current pulse response: impact of gamma

#1480-16, **3x10^{14} cm^{-2} + 500 Mrad** (higher F_n)

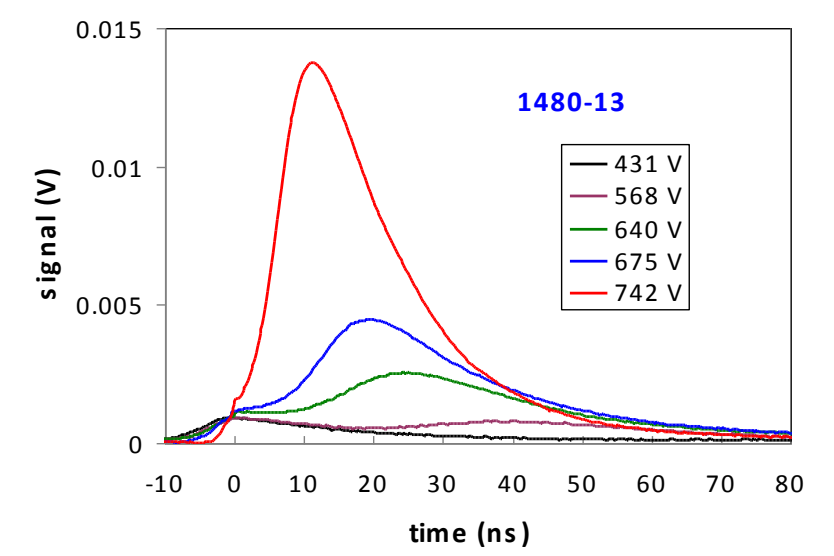


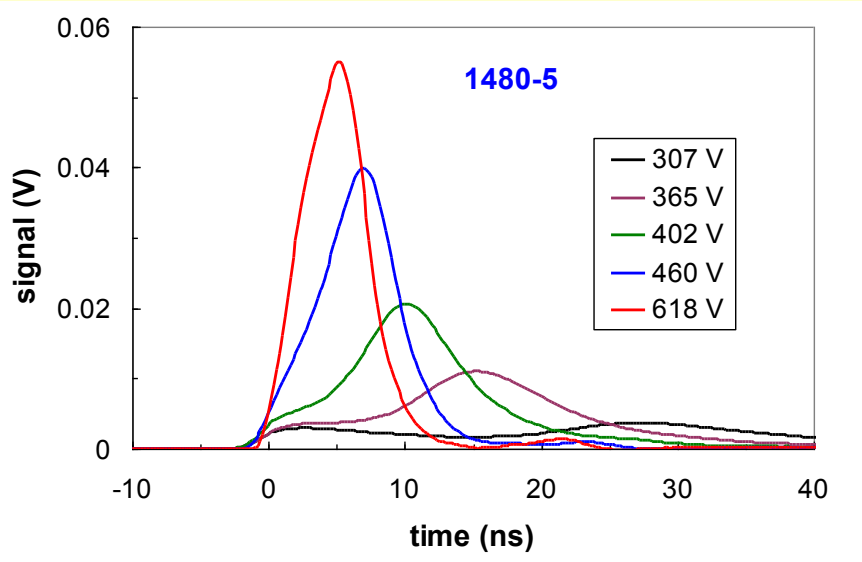


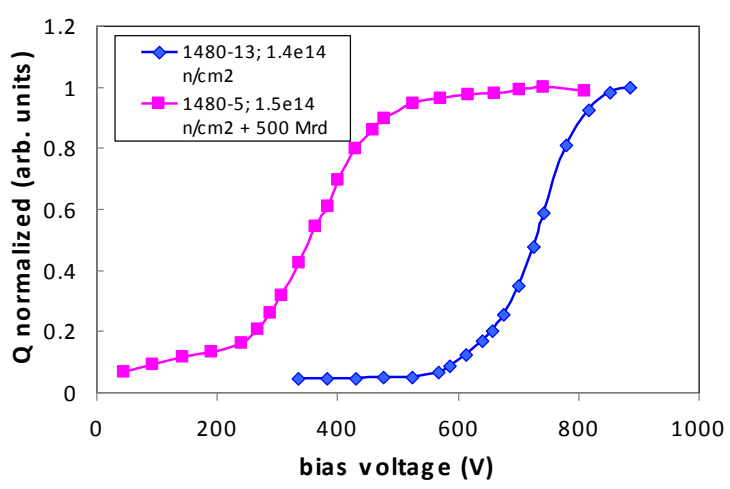
Pulse shapes and V_{fd} are also similar

Current pulse response: 12 month RTA

Lower F_n **3rd interval, end, RTA 12 months**







DP pulse shape arises at lower *V* in detector irradiated by gamma and is more pronounced

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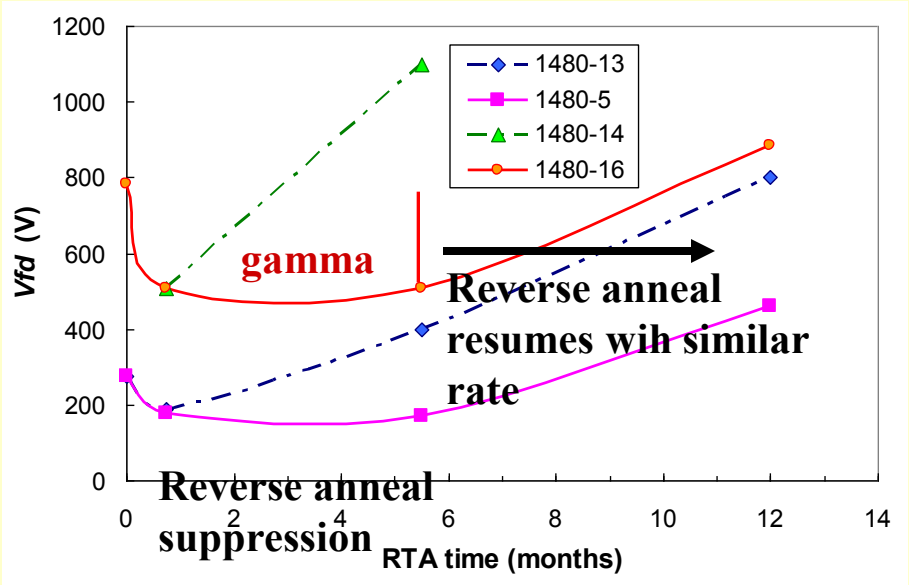
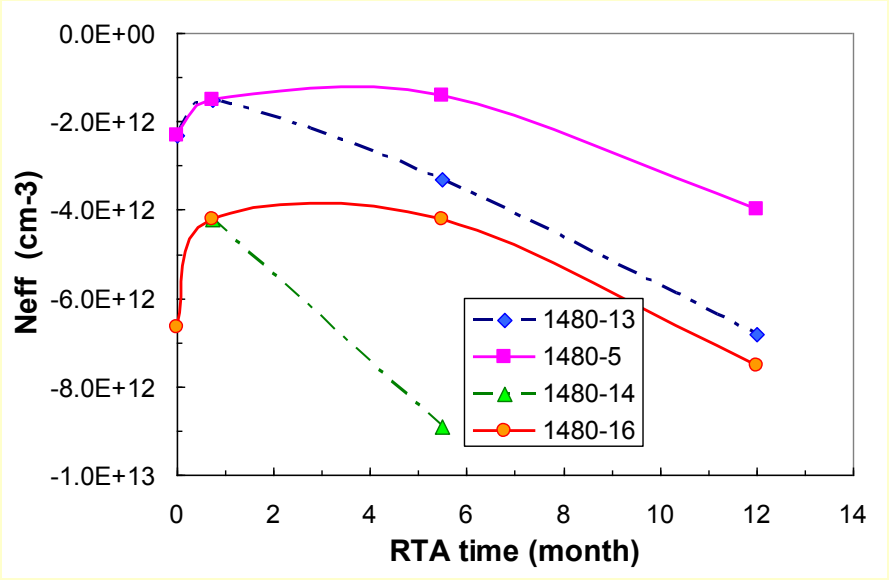
Evolution of V_{fd} and N_{eff} vs. RTA





F_n (n_{eq}/cm^2)	γ-dose after neutron irradiation during 5.5 m RTA (Mrad)	Changes in N_{eff} during 5.5 m RTA (cm^{-3})	Reverse annealing suppression	+SC would have been generated with gamma-radiation alone
$1.5x10^{14}$	500	$+0.1x10^{12}$	**completely**	**$+1.5x10^{12}$**
$3x10^{14}$	500	~0	**completely**	**$+1.5x10^{12}$**
$1.5x10^{14}$	0	$-1.8x10^{12}$	no	
$3x10^{14}$	0	$-4.7x10^{12}$	no	

Reverse anneal resumes even in gamma-irradiated detectors when gamma irrd. stops

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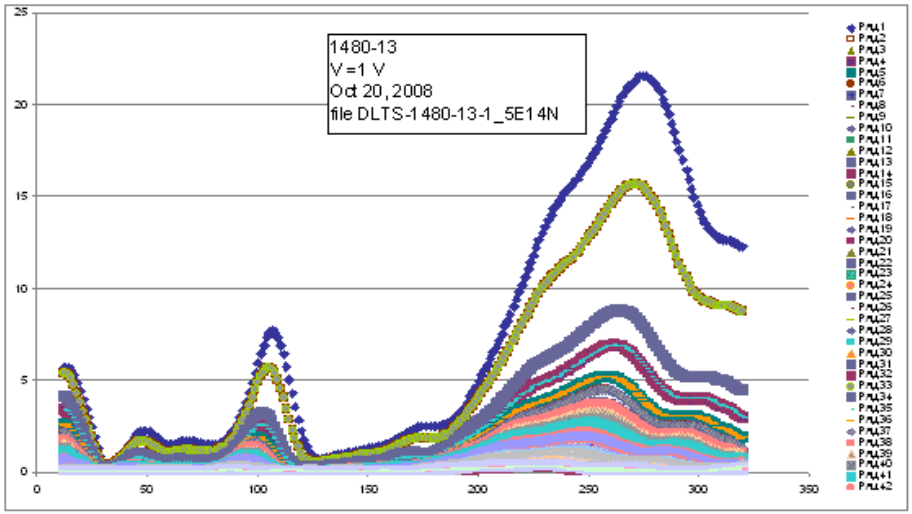
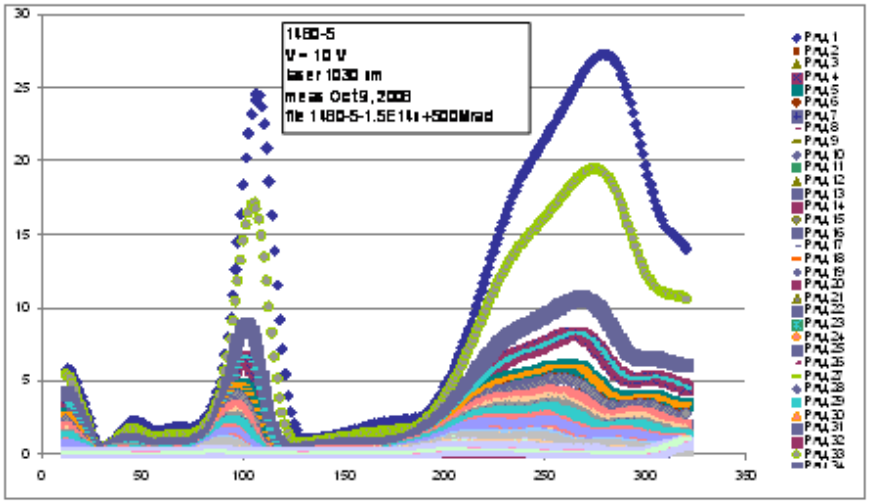
I-DLTS spectra

1480-13, only neutrons

RTA 5.5 months

1480-5, neutrons + gamma





100 K: A-center

200-300 K:
V^{--} + cluster defects

5.5 m RTA: 1480-13 $P_{100}/P_{300} = 0.36$

1480-5 $P_{100}/P_{300} = 0.87$

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Conclusions

In mixed irradiation neutrons + gamma:

- Complete suppression of reverse annealing occurs only during gamma irradiation, and disappears when gamma stops, and reverse anneal resumes with similar rate

2. Suppression is independent on applied F_n

3. Interaction of different defects?

4. DP/DJ effects are observed also for mixed irradiation

Acknowledgments

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Thank you for attention!